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A literature survey of toric hydrogel contact lenses

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Abstract
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<u>A Literature Survey of Toric Hydrogel Contact Lenses</u>

by

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Lens Verification

Probably one of the most important criteria of successful contact lens fitting is the accuracy of listed lens parameters. Many times these parameters are not as labeled[14,15,16,17] either due to manufacturing tolerances, mislabeling or the parameters change when it is packed, shipped, opened or worn. Because these dimensions are altered by temperature, tonicity, and hydration, it is difficult to determine their actual values with any degree of accuracy. Even if the label is correct and a good physical fit is obtained, the parameters may change during the course of daily wear. For this reason it is important that the lenses be verified before the dispensing and reverified when fitting or wearing problems develop.[18]

Appropriate in-office techniques for measuring five of the critical soft lens parameters are described by Janoff.[5] One important parameter not included in his discussion is the cylinder axis and power of toric lenses.

Personal communication with Dr. John Kohler, Director of Clinical Affairs for Barnes Hind Hydrocurve, has uncovered a clinically acceptable method of verifying toric lenses. Unlike Janoff's recommendation, the lens is placed with its concave surface away from the lensometer stop so that the front vertex power is measured. Though the accuracy of measuring the front vertex power as opposed to the back vertex power can be questioned, the reproducibility of the readings is greater with this technique. From a practical viewpoint the mechanical case of placing the lens in this manner produces results closer to the manufacturer's labeled parameters. Of course, the lensometer aperture must be in a vertical position for the lens to remain fixed. Some lensometers are designed with this provision while others can be propped up to approximately a vertical plane.

Position the lens such that the inferior base is at the six o'clock position and the lens is centered. If the lens contains prism ballasting of one prism diopter, then the mires should locate below the optical center at one prism diopter. If the mires are not located at the six o'clock position and it is accurately positioned on the lensometer stop, the lens is probably defective.

Power and axis can be read as with spectacles, however, the axis must be transposed since the front vertex power is being read. For example, if the lensometer reads 5 degrees, then the actual axis is 180 - 5 = 175 degrees. Many times the mires will simply not clear. Rewetting the lens and repeating the procedure is recommended at this point. If the mires still do not clear, the optics are poor and the lens is defective. It is important to use a lint free cloth or tissue (addresses of distributors included in Janoff's article) as lint will reduce optical clarity.

Methods of Stabilization

Critical to the success of a toric lens fit is the stability of the cylinder axis. Currently there are six ways to stabilize a lens.[2,29]

1. Back surface toric
2. Prism ballast
3. Truncation
4. Thin zones
5. Superior slab-off lenticular or periballast
6. Undercut carrier

Current toric lenses and their methods of stabilization are listed in the table in Appendix I.

Back Surface Toric

Only one of the currently available toric lenses incorporate the back surface toric design.[31] Whether this design contributes to the stability of the lens is still in question. Unlike the hard lens, a hydrogel lens conforms to the shape of the cornea. For this reason it is not readily apparent what affect the back surface toric lens will have on stability. In theory, the lens would conform to the toric cornea providing a better physical fit thus aiding in the stability of the lens.[20,28] Remba claims there is no optical or fitting advantage to either front or back surface toric designs since both assume bitoric characteristics and configuration when placed on a toric cornea.[19]

Jurkus et al.[20] in a study of sixteen subjects found that a 2.00 diopter with-the-rule cornea had less rotation with the back surface toric design. Spherical and lower toricities showed only marginal indications that favored back surface torics. Against-the-rule corneas of 1.00 diopter had less rotation with front surface torics, however, there were only two subjects in this category.

Prism Ballast

It is popularly believed that the prism ballast stabilizes the lens due to the gravitational pull created by its inherent weight differential. Although this is a possible explanation, Hanks[21] disagrees.[33,28,2] He maintains that those lenses which include a comfort chamfer or slabbing-off of the lower prism continue to stabilize in the eye despite reduced weight differential.

Henry Knoll[21] first coined the phrase "watermelon seed" principle, an analagous attempt to explain a principle of physics. The term refers to a moist seed squeezed between thumb and forefinger. The result, of course, is the expulsion of the seed by pressure in the direction opposite to the apex explaining an engineering principle related to pressure effects upon wedges. Hanks[21] went so far as to have a contact lens wearer stand on his head for fifteen minutes watching for lens rotation in the direction of gravity. It did not occur.

A distinct disadvantage of prism ballast is the added thickness of the lens which reduces the transmission of oxygen possibly compromising the physiology of the cornea[28,11] and reducing patient comfort. Generally the thickest part of the lens is located under the lower lid thus reducing lid sensation.[28] Manufacturers can also thin the region of the prism base without neutralizing the effect of the prism.[28]

One should also consider the flexing characteristics of the prism ballasted lens. Ewell states that a two base down prism added to a spherical soft lens induces -0.75 x 90 residual astigmatism.[39] He suggested that "the tilt of the prism lens relative to the incident rays striking its front surface, and the differential bending of the vertical meridian in which the prism is incorporated may account for the induced cylinder." Ewell apparently came to his conclusion by actually measuring cylinder power of soft lenses on his own eye by overrefraction. The accuracy of his methods remains a question. It is agreed that thicker spherical lenses do not conform exactly to the corneal topography,[41,42] and toric soft lens flexure is more complex.[28] Further research is needed to determine exactly how today's toric lenses are affected by lens flexure.

Truncation

According to Mandell[2] and Holden[28] a single, lower truncation provides only minimal efficiency. Prism ballast and a single truncation in combination has been used with success.[28,24]

Only two of the toric lenses listed in Table 1 incorporate truncation. Both include a prism ballast as well. Tomlinson, Schoessler, and Andrasko,[24] in an experiment with variable amounts of truncation and prism found the best combination to be 0.75 prism diopters with 0.5 mm truncation. Larger amounts of prism and truncation showed no further benefit.

Lenses with truncation have significantly more movement than spherical lenses with the same radial edge lift.[25] This may prove to be an advantage since additional movement facilitates greater oxygen interchange via the tear pump mechanism and thus aids corneal metabolism.[14]

A disadvantage of truncated lenses may be patient comfort. The location of the truncation either above or below the limbus in the primary position apparently makes no difference though one author preferred slightly above the limbus.[26] Dessication of the cornea does not occur at the truncation since the tear meniscus along the lower lid provides continuous hydration.

Thin Zones or Dynamic Stabilization

By thinning the superior and inferior margins of a lens, stabilization is achieved. This is accomplished by the tapering or a slab-off technique. The action of the lids riding over the thinned area will keep the lens from rotating.

In theory one would expect an against-the-rule correction to be more stable than with-the-rule since the lens would be thinner in the inferior and superior portions of the lens.[31] One study[27] found that success based on acuity was poorest for with-the-rule corneas as compared with oblique and against-the-rule. Unfortunately, only one subject represented the against-the-rule cornea so the study did not fully test the hypothesis. The study did, however, indicate success in the fitting of 9 out of 12 oblique cylinders. This design may be the lens of first choice for the more difficult cases of oblique cylinder.

The primary advantage of this design is in comfort from thin edges and a smooth round shape.[5] One author claimed that this design worked best with refractive errors of -3.00 diopters and above. Unless the lens is smaller than 15.0 mm in diameter, lenses of less than -3.00 diopters, and to include plus lenses, are design limited and can not be manufactured.[28]

Periballast or Superior Slab-off Lenticular

In this lens design the superior half of a minus lenticular carrier is removed producing the same effect as the prism ballast.[2,29] The main body of the lens containing the toric power has normal thickness. The diameter of the lens is cut off-center so that a large amount of carrier is left inferiorly and very little superiorly.

Since prism is not included in the optic zone, the center thickness will be similar to spherical lenses thus allowing more oxygen transmissibility. Salvatori claims a 33-1/3 percent reduction in center thickness.[29] The weight differential will be less than with prism ballasting which may decrease lens stability. A lack of an authoritative study comparing the two designs has been noted.

Undercut Carrier

This design also utilizes a minus lenticular carrier much like the periballast design. The bottom is cut eccentrically creating a ledge while the top is cut to a normal thickness. The ledge will then aid in stability due to its interaction with the lower lid.[29]

Fitting

Fitting the toric lens can be a frustrating experience for the practitioner. With careful, accurate findings in conjunction with an understanding of toric lens optics, fitting can be a success. It should be noted that most manufacturers provide a fitting guide which in all cases should be consulted first.

Accurate baseline information should include the following:

keratometry
refractive error
tear break-up time
schirmer test
slit lamp evaluation

Patient selection for toric lenses is the same as for spherical soft lenses, but with an additional few considerations.

The patient with low cylinder (1.00 diopter or less) should try a spherical lens first because the toric lens provides no benefit over the spherical lens in many of these cases.[30,19] Since patients with higher spherical errors are less aware of residual astigmatism, Remba recommends a 4-to-1 rule of thumb.[19] If the refractive cylinder is no more than one quarter of the sphere value, try spheres first using the equivalent sphere power as the lens of first choice. Another case that needs special consideration is the patient with low sphere and moderate to high cylinder as these tend to have low success.[31]

With current lens designs, resultant acuity of 20/20 even when a potential of 20/15 exists is wholly acceptable.[26] Further improvement may not be possible. Therefore, the patient who is extremely sensitive to slight prescription changes or who spends many hours a day doing close work may not be a candidate for these lenses.[31]

Also contraindicated may be the patient with narrow palpebral apertures or very tight eyelids. This latter case may have problems with axis location and rotation.[31]

To begin the fitting procedures, most manufacturers recommend trial lens fitting or inventory fitting. It is theoretically possible to order directly from baseline information, but there is no literature to date recommending such a procedure.

Trial lenses can be either spherical or toric. The advantage of the spherical trial lens is that the resultant prescription is easy to calculate from the over-refraction. The fact that the final lens ordered may not behave in the same manner as the trial lens is the primary criticism of this method. Designs that use the thickness profile of the lens as a means of stabilization (prism ballast, thin zones) may show a difference in the rotational characteristics of the final lens ordered. The B&L Toric and the Ciba Torisoft have a spherical periphery in both the diagnostic set and the full cylinder prescriptions. They claim to have better agreement between the spherical trial lens and the toric lens ordered.[21]

The toric trial lens set will come closer to the final lens and, therefore, eliminate most errors. The optics, however, are complicated with the addition of crossed cylinders. There are reference tables (13, 28, 32, 33) and computer programs[34] to aid in these calculations. Alternatively, one is able to place over-refraction powers and the toric trial lens powers in a trial frame and verify the combination in a lensometer.

Inventory fitting has the advantage of same day dispensing and convenience, but could be costly to maintain. One practitioner claimed that it may be hard to explain to a patient why it cost $450 for lenses that supposedly require complicated and extensive fitting when the lenses are simply tried on and dispensed.[12]

When doing a spherocylindrical over-refraction with a stable toric lens in place, one rule-of-thumb suggested by Dr. John Kohler, Clinic Director, Barnes Hind Hydrocurve, is to "follow the over-refraction axis" when rotation has occurred just as you would "follow red" in the Jackson Cross Cylinder test. The second lens should have an axis closer to the over-refraction axis.

Evaluating lens rotation is a critical factor with toric lenses. Manufacturers generally provide some method of marking the lens to do this. Common markings include ink, scribe lines, engraved dots, laser trace, and truncation.[35] Ink and truncation are most easily seen but both have limitations. Ink may fade or be complicated by a possible physiological incompatibility.[36] If truncation is used as a means to measure lens orientation, the final prescription must also be truncated.[35] One may not want to accept decreased patient comfort or additional processing for a truncation. Scribe lines are most commonly used but may present a mechanical weak point in the lens.[35] Dots are hard to see and can be made more visible by dotting the lens with ink. Laser trace markings are easy to see, easily aligned, and are claimed to present no resultant lens weakening.[37,38]

There are three methods for observing lens orientation.

1. Slit lamp eye piece with an axis reticule
2. Rotating slit and axis scales
3. Marked plano lens in a trial frame

The slit lamp eye piece can be an expensive venture but may prove to pay for itself in time saved. Kohler[30] describes the use of protractor tapes (see Appendix II) used in conjunction with the rotating beam of the slit lamp. Some manufacturers provide these tapes.

The use of the trial frame with a marked plano lens (explained in Appendix II) is an effective method, but includes more steps than the other two methods. When using the marked plano lens in the slit lamp, the microscope may need to be racked back and forth because of the limited depth of focus.

With a little skill, the practitioner may be able to estimate lens rotation with the simple remembrance that one hour of the clock face is 30 degrees.

To remember whether to add or subtract the rotation of the trial lens to the patient's cylinder axis consider the clock face again. When moving clockwise one increases time by one hour, therefore, add. When going counterclockwise the hours decrease. Therefore, with clockwise rotation, add and with counterclockwise rotation, subtract. Also note that if the rotation exceeds 20 to 25 degrees, a fitting problem is probable and the physical fit should be checked.[26]

A quick way to check axis alignment is by "dialing".[12] Have the patient observe a small Snellen acuity line then use your finger or the end of a hard contact lens remover to dial the axis of best acuity. If better acuity can be achieved by rotating the lens, then re-evaluate the lens. A quick check with hand held spheres will determine the sphere power at the best axis location.

A trial lens should be left in the eye 30 minutes or less if tearing subsides and the eye appears to be adjusted.[43] In most cases the rotation of the lens is the same at 4 hours as it is at 30 minutes.[40] At this time the lens can be evaluated for both physical and optical fit by slit lamp examination and the over-refraction.

Tables 2 and 4 in Appendix III provide a checklist of criteria describing a well-fitted lens, a steep lens, and a flat lens. A good physical fit will show no rotation with blinking and a fast recovery rate if the lens is mislocated. Manually move the lens off-axis, then have the patient blink normally. The fewer blinks, the better the recovery rate.[31] The recovery rate can also be checked by having the patient squeeze blink in the primary and superior gaze.

One complaint of toric lenses is poor near vision.[31] White and Scott identified three major reasons for this:

1. Binocular or accommodative problems.
2. Reduction of blinking and fixation changes, resulting in poorer wiping and fluid interchange, as well as lens dehydration.
3. Improperly corrected distance refractive error.

Many times the toric lens patient is not corrected fully due to manufacturer tolerances, also having a greater effect at near than at far.

With the different lid position and convergence activity upon near fixation, the rotation of the axis and the flexure of the lens may be different. The eye may also be looking through a different portion of the lens. With the prism ballasted lens this could be a significant difference. Evaluating these changes when reading is difficult. It may be sufficient to screen patients who do many hours of near work as mentioned earlier. Minimally the practitioner must alert the patient to the possibility of reduced acuity at near.

Another common complaint is reduced vision after periods where vision was good. In this case either the len has accummulated deposits that cloud the optics or some factor in the environment has caused the lens to dry. A lens will lose approximately 10 to 20 percent of its water content with wear.[28] Any number of environmental factors could cause drying such as air conditioning, dry climate, and wind. Some physiological variables can alter the tear composition, including such conditions as hormonal contraceptives, which change the mucous composition in the tears.[33] The changing hydration of the lens will alter the parameters, possibly causing the lens to orient differently or change in power.

Other than prescribing artificial tears, very little can be done for transient drying of the lens short of changing the lens material. Most manufacturers recommend artificial tears for extended wear lenses. This may be beneficial to the toric lens wearer as well.

Complications for toric soft lenses are the same as for spherical soft lenses although more attention to corneal physiology is indicated, due to the increased thickness of the lenses.

Manufacturing Methods

Toric soft lenses are presently lathe cut.[31] This mode of manufacturing makes it possible to produce a wide variety of lens designs. Because the initial material is hard like the PMMA (polymethylmethacrylate) material, any lens that can be made in the hard lens design can be duplicated in a lathe-cut gel lens.[2]

The disadvantage of the lathe-cut lens design is the problem inherent in the expansion process once the lens is hydrated. During hydration every dimension of the lens changes including the index of refraction and the refractive power.[2] A correction factor must be applied to predict the final dimensions after hydration.

The cost of toric soft lenses is considerably more than spherical soft lenses due to this costly manufacturing process. Furthermore the final lens parameters are often not as specified on the label.[11] Manufacturers are researching toric lathe cutting (as opposed to the spherical lathing procedure used today), casting, and improvements in the crimping procedure.[31]

Molded, spin-cast hydrophilic spherical soft lenses are currently available from A.O., B & L, Cooper Vision, American Hydron, and Ocular Sciences. In spite of the inherent advantages of these lenses - better reproducibility, reduced product expense, faster and more accurate production - the literature uncovered only one clinical evaluation of a toric molded soft lens produced by American Hydron.

Conclusion

Upon reading this review of soft toric lens research one will not become an expert. Hopefully, however, the reader will have a more clear understanding of their limitations, possibilities, advantages, and complications. With the swift changes taking place in contact lens technology, the practitioner must have more than just a casual interest in this area. A knowledge of lens material, manufacturing techniques as well as procedures for verification and fitting is an absolute must to best serve the patient. This review should serve as a starting point for the practitioner in his/her continual review of new techniques and research.

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Appendix I

Table 1. Courtesy White, P and Scott, C. Update: Toric Soft Contact Lenses. Contemporary Optometry, 1982, 1(1):19-24.

Extended and Daily Wear F.D.A.–Approved and Available Inventory Soft Toric Lenses

Trade Name	Manufacturer	% Fluid	Dk*	Base Curves	Diameters	Spherical Power Range	Cylinder Powers	Cylinder Axes (degrees)	Reference Marks	Stabilization Method
Hydrocurve II, 55%	Soft Lens San Diego, CA	55	12	8.8	14.5	Pl to −6	1.25	180 ± 25 90 ± 25 in 5° steps	3 lines at bottom separated by 20°	1 prism diopter
Daily Wear F.D.A.–Approved and Available Inventory Soft Toric Lenses										
B&L Toric	Bausch & Lomb Rochester, NY	45	8	8.3 8.6	14.0	+4 to −6	1.25 and 1.75	180 ± 20 90 ± 20 in 10° steps	3 lines at bottom separated by 30°	1 prism-diopter and inferior chamfer
Durasoft** ***	Wesley Jessen Chicago, IL	30	3	8.45 8.60	12.8 13.5	−1 to −6	1.25 and 2.00	180 ± 15 90 ± 15 in 5° steps	truncation	.75 prism diopter and .75 mm truncation
Hydrocurve II, 45%	Soft Lens San Diego, CA	45	8	8.6 8.9	13.5 14.5	+3 to −8	1.25 and 2.00	180 ± 25 90 ± 25 in 5° steps	dot at base	1 prism diopter
Hydromarc	Frontier Contact Lens (Vistakon, Inc.) Jacksonville, FL	43	9	8.30 (Series 1) 8.75 (Series 2) 9.05 (Series 3)	14.5	Pl to −5 (+.25 to +4.00 available soon)	0.75 to 2.00 in 0.25 steps	180 ± 20 90 ± 20 in 5° steps	dot at base	1.5 prism diopters and inferior slab-off
Sof-Form	Sof-Form, Inc. Sarasota, FL	43	9	8.7	14	−.75 to −6	1.25 and 2.00	180 ± 30 90 ± 30 in 15° steps	scribe at base	periballast with centered optic zone
Tori-Soft	Ciba Vision Care Atlanta, GA	37.5	9	8.6 8.9 9.2	14.5	Pl to −6	1.00 and 1.75	180 ± 20 90 ± 10 in 10° steps	horizontal lines at extremities of 180°	superior and inferior slab-off
Daily Wear F.D.A.–Approved and Soon-to-be-available Inventory Soft Toric Lenses										
Hydron**	American Hydron Woodbury, NY	38.6	8	8.4 8.7	14.2 horizontal by 13.2 vertical	Pl to −6	0.75 to 2.00 in 0.25 steps	180 ± 20 in 5° steps	truncation	.75 prism diopter and 1 mm truncation

*There is some discrepancy among Dk numbers reported in the literature by various investigators. The numbers used in this chart are based upon averaging of the reported Dks taken at room temperature, rounded to the nearest whole number, and expressed as 10^{-11}.

**The Durasoft and Hydron lenses are also available on a custom-designed basis with a large range of parameters.

***A Durasoft 2 is available in 38% fluid, 14.5 mm diameter, 8.6mm base curve, 1.25 and 2.00 cylinders.

Appendix
Measuring Toric Lens Orientation

1. Using a wax marking pencil or a fine felt-tip pen, join the axis markings on a low cylinder trial frame lens to form a line across the lens.

2. After the toric contact lens has been on the eye for 30 minutes, place the trial frame with the trial lens in it on the patient's face. Be sure the patient is blinking normally and tearing has subsided.

3. Position patient at the slit lamp. It is important that the trial frame be correctly set on the patient's face in order not to introduce errors in the axis measurement.

4. Focus and rotate the slit lamp beam through the trial lens so that the slit lamp beam is coincident with the contact lens truncation.

5. Rotate the trial lens so that the line drawn on it in Step 1 is parallel with the slit lamp beam.

6. Read off and record the number of degrees the line is from the 0-180 horizontal (must always be an acute angle).

7. Record the direction of rotation as either nasal portion of truncation up or temporal up.

8. Using standard notation, to compensate the axis of the newest spectacle Rx for a contact lens axis, use the following guidelines:

- Right eye — nasal up (counter-clockwise): subtract acute angle from spectacle Rx axis.
- Right eye — temporal up (clockwise): add acute angle to spectacle Rx axis.
- Left eye — nasal up (clockwise): add acute angle to spectacle Rx axis.
- Left eye — temporal up (counter-clockwise): subtract acute angle from Rx axis.

9. Example: On the right eye the lens truncation rotates nasal up or counter-clockwise and reads 12 degrees on the trial frame.

Spectacle Rx:	- 1.00 - 2.00x180
	- 12
Contact lens Rx:	- 1.00 - 2.00x168

On the left eye, the lens truncation rotates nasal up or clockwise and reads 169 degrees on the trial frame. It is rotating (180-169=11°) *11 degrees nasal up.*

Spectacle Rx:	- 1.50 - 1.50x170
	+11
Contact lens Rx:	1.50 - 1.50x061

Courtesy of Raskin, N. Fitting Hydron Toric Lenses. Contact Lens Forum, January 1982, 103-110.

PROTRACTOR TAPE FOR SLIT LAMP HOUSING

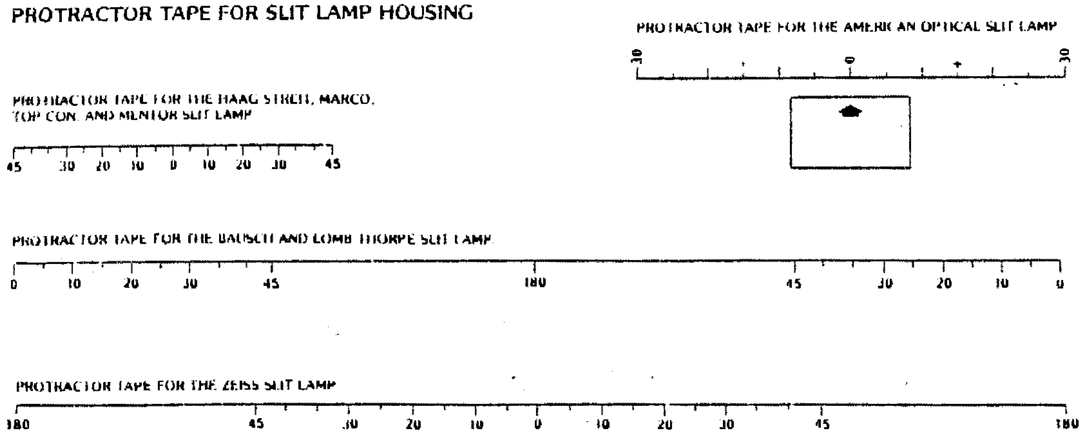

Figure 1

Figure 1. Suggested protractor tapes — to scale.

Courtesy of Malin, A.H. and Kohler, J. Measuring Toric Rotation. Contact Lens Forum, October 1981, 17-23.

Appendix III

Table 4. Characteristics of a Loose (Flat) Toric Soft Contact Lens

- ☐ Decentration (usually temporally and/or superiorly).
- ☐ Excessive up gaze movement with the blink.
- ☐ Excessive up gaze lag.
- ☐ Reduced comfort response—usually lower lid sensation.
- ☐ Lens orientation unstable and inconsistent.
- ☐ Lens edge standoff and buckling.
- ☐ Unstable vision.

Table 2. Criteria of a Well-Fitted Toric Soft Contact Lens

- ☐ Full corneal coverage
- ☐ Good centration (concentric about the visible iris).
- ☐ Satisfactory movement (in up gaze 0.5mm movement with the blink is ideal).
- ☐ Satisfactory lens lag (in up gaze, lens lag of 0.5 – 1.0mm is ideal).
- ☐ Satisfactory comfort response by the patient.
- ☐ Stable lens orientation with consistent return if lens is mislocated.
- ☐ Satisfactory vision response by the patient (vision should be comparable to best spectacle acuity).

Table 3. Characteristics of a Tight (Steep) Toric Soft Contact Lens

- ☐ Good centration.
- ☐ Little or no up gaze movement with the blink.
- ☐ Little or no up gaze lag.
- ☐ Good comfort.
- ☐ Blurred vision which clears immediately following blink.
- ☐ Stable lens orientation but slow return if lens is mislocated.
- ☐ Bubble(s) under the lens.
- ☐ Conjunctival indentation and/or blanching of limbal vessels at the lens edge.
- ☐ Limbal-conjunctival hyperemia.

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Courtesy of Hanks, A.J. and Weisbarth, R.E. Troubleshooting Soft Toric Contact Lenses. 1983, 10(5):305-317.